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GROUND WATER IN THE SAN JUAN BASIN, NEW MEXICO AND COLORADO

WATER-RESOURCES INVESTIGATIONS 79-73

PREPARED IN COOPERATION WITH THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, THE NEW MEXICO STATE ENGINEER, AND THE BUREAU OF INDIAN AFFAIRS' SAN JUAN REGIONAL URANIUM STUDY

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. Abstracts

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By Forest P. Lyford

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MAY 1979

UNITED STATES DEPARTMENT OF THE INTERIOR

Cecil D. Andrus, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

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Albuquerque, New Mexico 87125

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Illustrations

Inch-pound unit to metric unit conversion factors

In this report figures for measurements are given in inch-pound units only. The following table contains factors for converting to metric units.

Multiply inch-pound unit	By	To obtain metric unit
in (inch)	25.40	mm (millimeter)
ft (foot)	0.3048	m (meter)
ft^2/d (foot squared per day)	0.09290	m^2/d (meter squared per day)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)
gal/min (gallon per minute)	0.06309	L/s (liter per second)

Ground water in the San Juan Basin, New Mexico and Colorado

By Forest P. Lyford

Abstract

Principal aquifers in the San Juan Basin of New Mexico and Colorado are the Entrada Sandstone, Westwater Canyon Member of the Morrison Formation, Gallup Sandstone of the Mesaverde Group, several sandstones in the Mesaverde Group above the Gallup (Dalton Sandstone Member of the Crevasse Canyon Formation, Point Lookout Sandstone, Menefee Formation, Cliff House Sandstone), and sandstones of Tertiary age.

Most ground water flows from topographically high outcrop areas toward the San Juan River and Rio Grande valley. Much of the water may move through confining layers to other aquifers or to the land surface rather than discharging directly to the streams.

Transmissivities of the sandstones range from 50 to 300 feet squared per day. Lowest dissolved-solids concentrations occur in or near outcrops of the sandstones and increase in the direction of ground-water flow. Concentrations range from less than 500 milligrams per liter to more than 30,000 milligrams per liter.

Introduction

Purpose

In anticipation of increasing demands for water for energy-related activity, a study of ground-water resources of northwestern New Mexico in cooperation with the New Mexico Bureau of Mines and Mineral Resources and the New Mexico State Engineer was begun in 1974 to: (1) determine the availability of ground water and (2) determine effects of anticipated ground-water development on water levels, streamflow, and water quality. This report, which was

prepared at the request of the Bureau of Indian Affairs' San Juan Basin Regional Uranium Study Task Force, summarizes the ground-water environment in 1978, based on results that were obtained as a part of the cooperative study. The data used for this summary are on file in the U.S. Geological Survey office in Albuquerque, N. Mex. A data report is in preparation.

Study area

The study area coincides approximately with the San Juan structural basin as defined by Kelley (1951). The boundaries of the study area include the San Juan and La Plata Mountains of Colorado on the north side, the Defiance uplift and New Mexico-Arizona State line on the west side, the Zuni Mountains and Interstate 40 on the south side, and the Nacimiento uplift and Rio Grande rift on the east side (fig. 1). This area covers about 18,000 square miles. Population centers include Durango and Cortez, Colorado and Farmington, Gallup, and Grants, N. Mex.

Mean annual rainfall in the basin varies from about 6 inches at lower elevations to more than 20 inches in mountains.

The San Juan Basin is rich in energy resources. Oil production began near Shiprock in the early 1900's and continues in several fields (fig. 2). Since the 1950's, natural gas produced from a large area near the center of the basin has been the principal hydrocarbon product. Surface coal mining and mine-mouth power generation began in 1962 near Farmington. Surface mining has also produced coal near Gallup since 1961 (Shomaker and others, 1971). Uranium production in the Grants mineral belt on the south end of the basin (fig. 2) has been one of New Mexico's principal industries since the 1950's.

Proposed energy-resource developments include several surface coal-mining operations in the Fruitland coal area, underground mining of coal seams in the Menefee Formation near Cuba, and surface mining of coal seams in the Menefee near Crownpoint. The feasibility of installing at least one additional power plant is being studied. Numerous underground uranium mines have either been started or are in the planning stage throughout most of the Grants mineral belt.

An industry of considerable importance is the Navajo Indian Irrigation project south of Farmington, which will add 110,000 acres of irrigated land by 1986. Irrigation began on the first 10,000-acre tract in 1976.

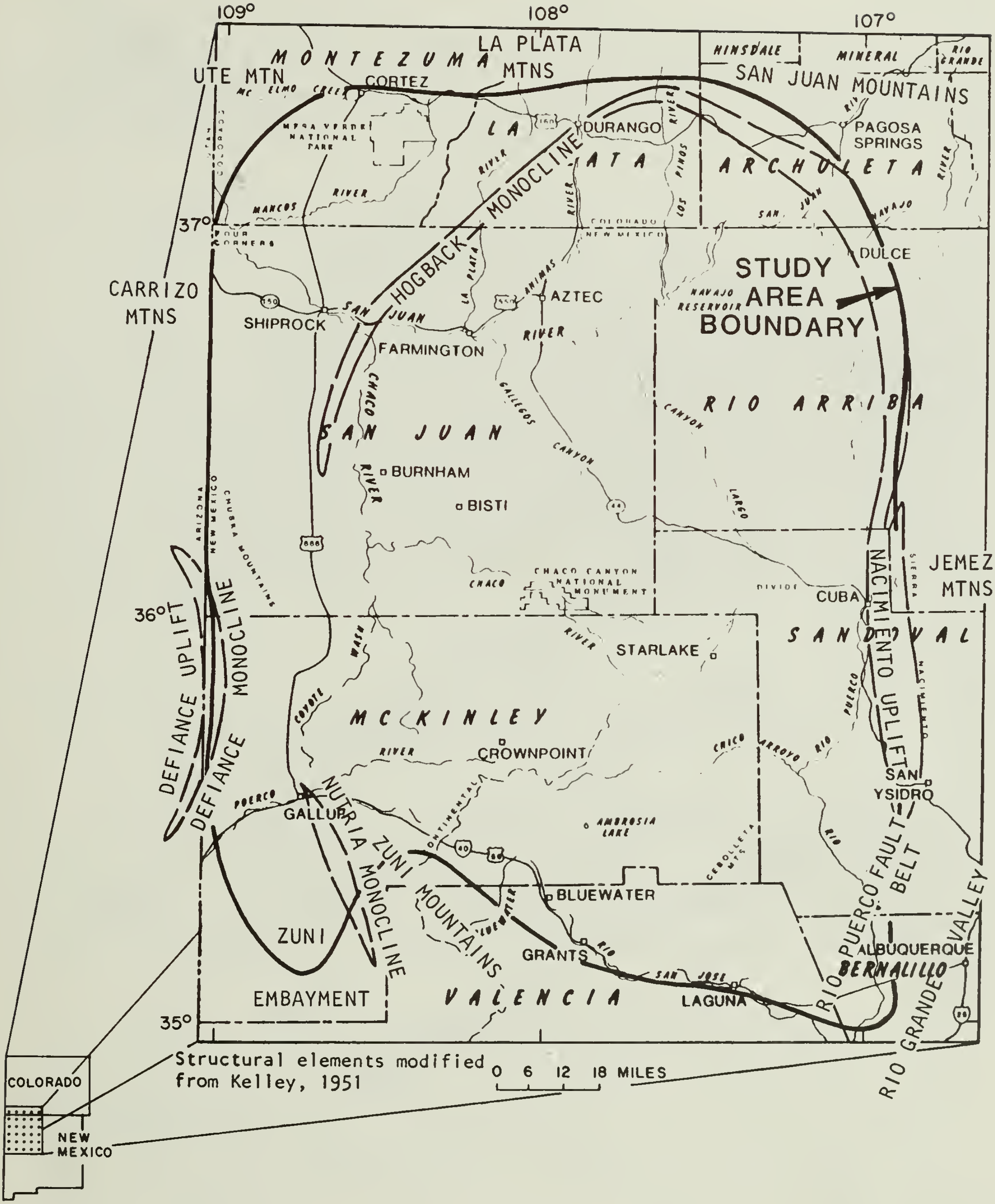


Figure 1.--Structural elements of the San Juan Basin and location of the study area.

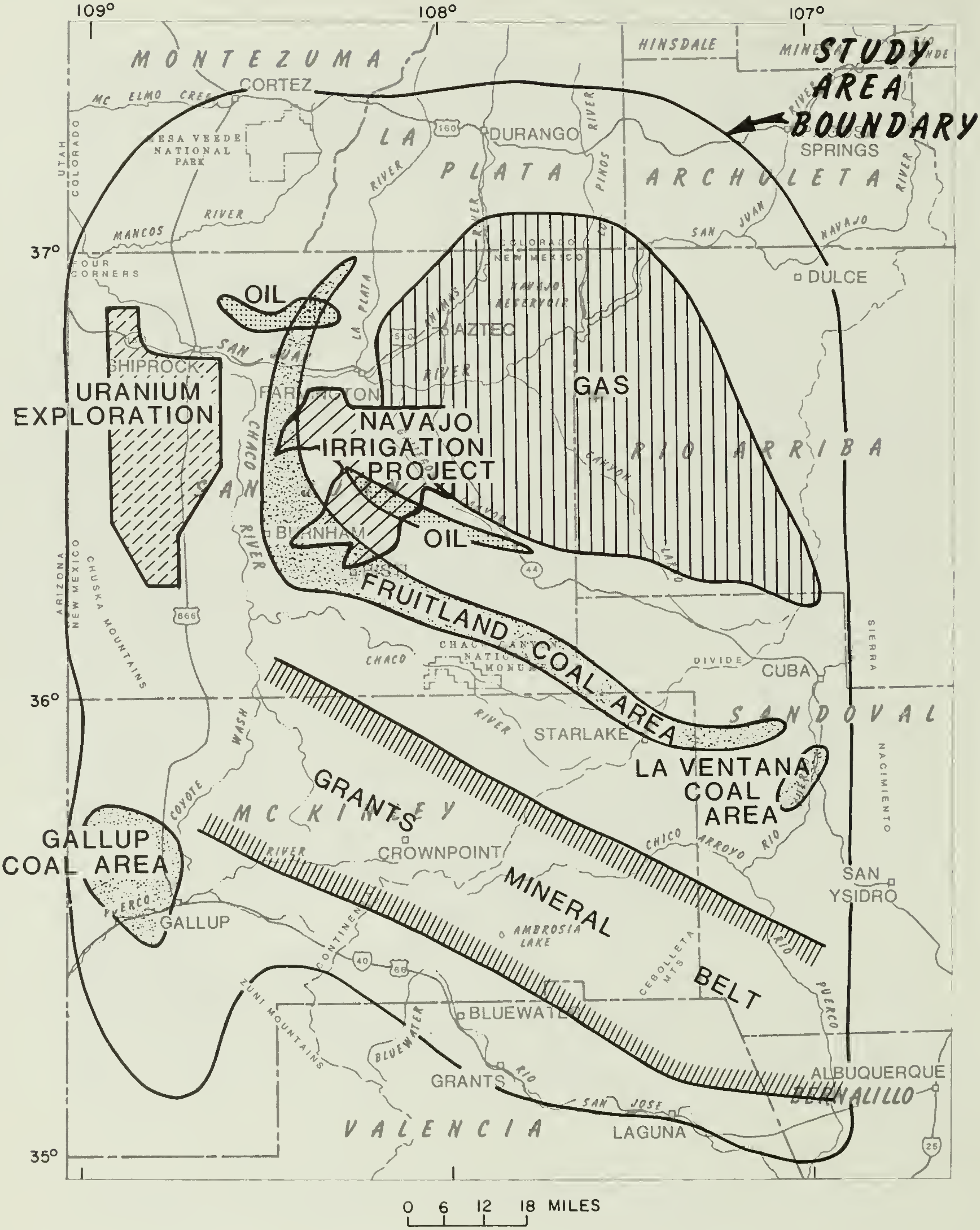


Figure 2.--Major areas of current and proposed resources development in the San Juan Basin.

Rapid population increases are occurring in the larger cities--Farmington, Gallup, and Grants. Expansion and economic growth may soon take place in smaller towns near areas of major industrial development.

Sources of ground-water data

Parts of the San Juan Basin have been studied in varying degrees of intensity starting with Gregory's reconnaissance of the Navajo Country during the early 1900's (Gregory, 1916). Later investigations include those by Baltz and West (1967) of part of the Jicarilla Reservation; Cooper and John (1968) of southeastern McKinley County; and Cooley, Harshbarger, and others (1969) of the Navajo Reservation. Other important sources of data are given in the list of selected references. The Navajo Tribe has kindly supplied data for many water wells drilled since the 1950's. Various coal, uranium, and petroleum companies working in the area have also supplied extremely useful hydrologic data.

Geologic setting

Geologic units in the San Juan Basin range in age from Cambrian to Quaternary. With the exception of the Permian San Andres Limestone and Glorieta Sandstone near Grants, the better aquifers are found in sandstones of Jurassic, Cretaceous, and Tertiary age. Quaternary deposits filling stream channels are capable of yielding sufficient quantities of water for stock and domestic use in many areas.

Aquifers discussed in this report are Jurassic age or younger. These include, in ascending order, the Entrada Sandstone, the Morrison Formation (principally the Westwater Canyon Member), the Gallup Sandstone of the Mesaverde Group, younger sandstones of the Mesaverde Group (Dalton Sandstone Member of the Crevasse Canyon Formation, Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone), and the Tertiary section (the Ojo Alamo Sandstone, Nacimiento Formation, San Jose Formation, and Chuska Sandstone). All aquifers are separated by shale units. The oldest rocks crop out on the edge of the basin and dip under younger rocks toward the deepest

part of the basin near Navajo Reservoir. Figure 3 shows the major aquifers in a highly generalized section through the deepest part of the basin. Detailed descriptions of some of the sandstone aquifers are given by Shomaker and Stone (1976). General descriptions of most geologic units in the San Juan Basin are given by Ridgley and others (1978).

Many discontinuous faults of small displacement exist throughout the basin. These faults may be significant conduits for the inter-aquifer transfer of ground water. Two major structural features--the Hogback Monocline in the northwest and the Rio Puerco fault belt at the edge of the Rio Grande valley (fig. 1)--strongly affect the ground-water flow regime in these localities because of water movement along vertical fractures.

Principal aquifers

Entrada Sandstone

Recharge to the Entrada Sandstone occurs mainly in or near topographically high outcrop areas on the edge of the basin (fig. 3) either by direct infiltration or by leakage from overlying and underlying aquifers. Most ground water moves toward outcrops in Utah near Four Corners and in the Rio Grande rift. Some of the water may be discharged by leaking to other aquifers or to the land surface before reaching the outcrops.

Transmissivity is "the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient" (Lohman, 1972, p. 6). Limited data for the Entrada Sandstone indicate that transmissivities toward the center of the basin are higher than near the edge of the basin. Measured values of transmissivity near Chaco Canyon National Monument range from 100 to 300 ft^2/d (J. W. Shomaker, oral commun., 1978) in contrast to values of less than 50 ft^2/d near outcrop areas on the south and west sides of the basin. Insufficient data are available for construction of a map showing transmissivity and flow directions.

Water quality in the Entrada Sandstone deteriorates toward the center of the basin. Dissolved-solids concentrations normally increase in the direction of flow. Dissolved-solids concentrations of 1,000 mg/L or less occur in or near recharge areas south of Crownpoint and in the Chuska Mountains. Concentrations of 10,000 mg/L or more toward the center of the basin may be partly attributed to the dissolution of soluble minerals in the Entrada. Also of importance may be the dissolution of evaporites in the overlying Todilto Limestone. Insufficient data are available for construction of a map showing water quality.

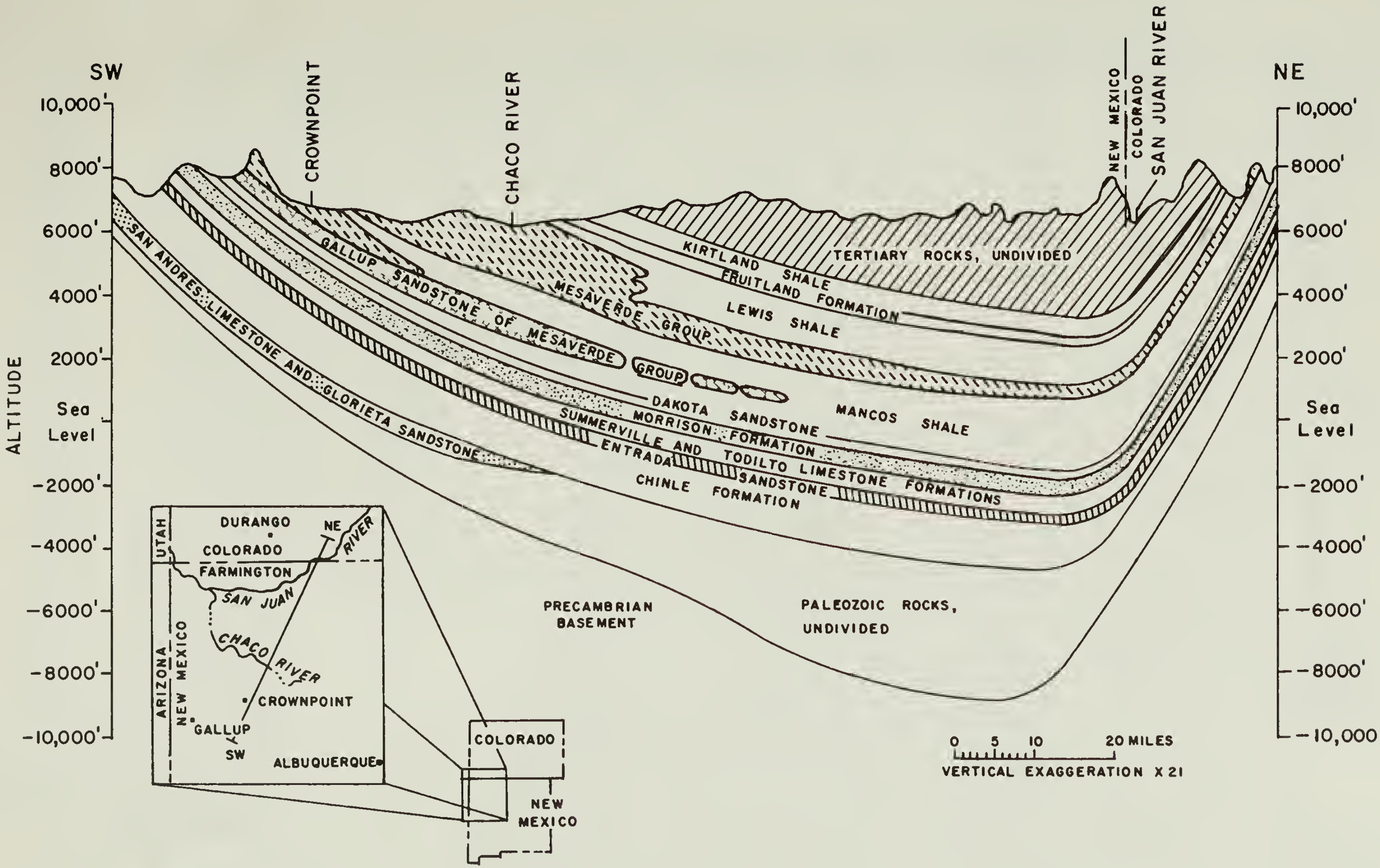


Figure 3.--Generalized geologic section showing major aquifers (patterns) in the San Juan Basin.

Morrison Formation

Water recharged to the Morrison Formation on or near high outcrop areas moves toward Four Corners and the Rio Grande valley as shown in figure 4. A relatively small amount moves toward the Puerco River southwest of Gallup. Much of the recharged water may leak to shallower units or to the land surface.

The transmissivity in the Morrison Formation ranges from 300 ft^2/d at the southwest end of the basin to less than 50 ft^2/d in the northeast (fig. 4). The higher transmissivities occur in coarser-grained, thicker sandstone units in the Morrison Formation (Kelly, 1977, p. 287).

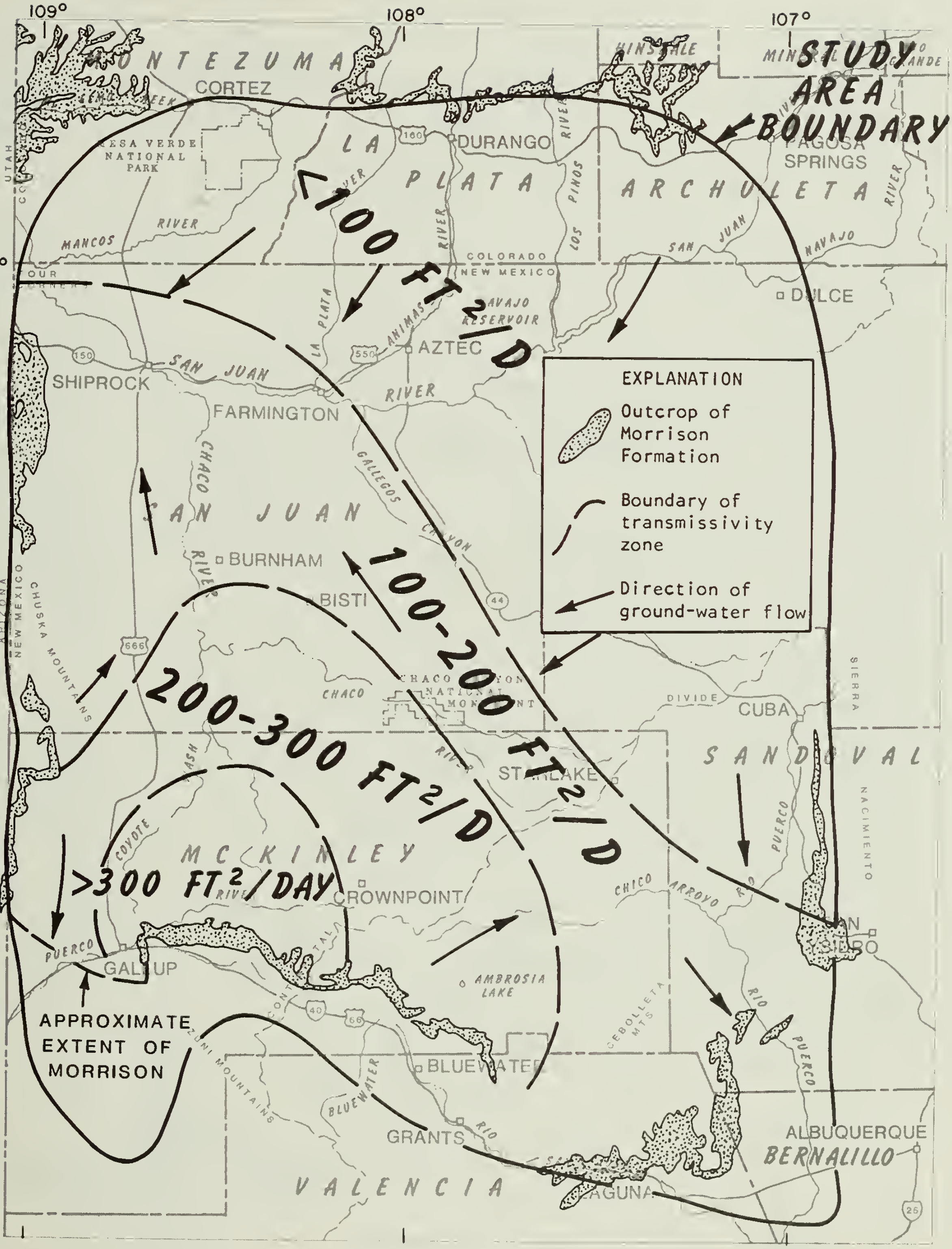
Dissolved-solids concentrations range from less than 500 mg/L in or near recharge areas in the southwest part of the basin to more than 4,000 mg/L toward the center of the basin (fig. 5). Water moving toward the San Juan River in the Four Corners area is a mixture of fresh water from recharge areas in the Chuska Mountains and saline water from deeper parts of the basin. Saline water moving toward the Rio Grande valley mixes with somewhat less saline water from the west. Dissolved-solids concentrations of this mixture exceed 4,000 mg/L.

Morrison water pumped from mines near Ambrosia Lake has locally higher dissolved-solids concentrations (greater than 1,000 mg/L) than are mapped on figure 5. These local differences can be attributed to alteration of minerals in the mines by oxidation and to recirculation of pumped water.

Gallup Sandstone of the Mesaverde Group

Recharge to the Gallup Sandstone of the Mesaverde Group occurs in or near outcrops of strata on the south and west sides of the basin. Most of the water moves northwestward and northeastward, but smaller quantities move toward the Puerco River in the Gallup area (fig. 6). Because the massive part of the Gallup does not crop out at the San Juan River, the water moving toward the northwest must leak to shallower or deeper units.

Transmissivities of the Gallup Sandstone range from more than 200 ft^2/d near Gallup (Mercer and Lappala, 1972) in the coarse, thick sands to less than 100 ft^2/d near the northeastward extent of the massive sandstone (fig. 6).



Geology modified from:
C.H. Dane and G.O. Bachman (1965) and O. Tweto (1976)

Figure 4.--Transmissivity and direction of ground-water flow in the Morrison Formation.

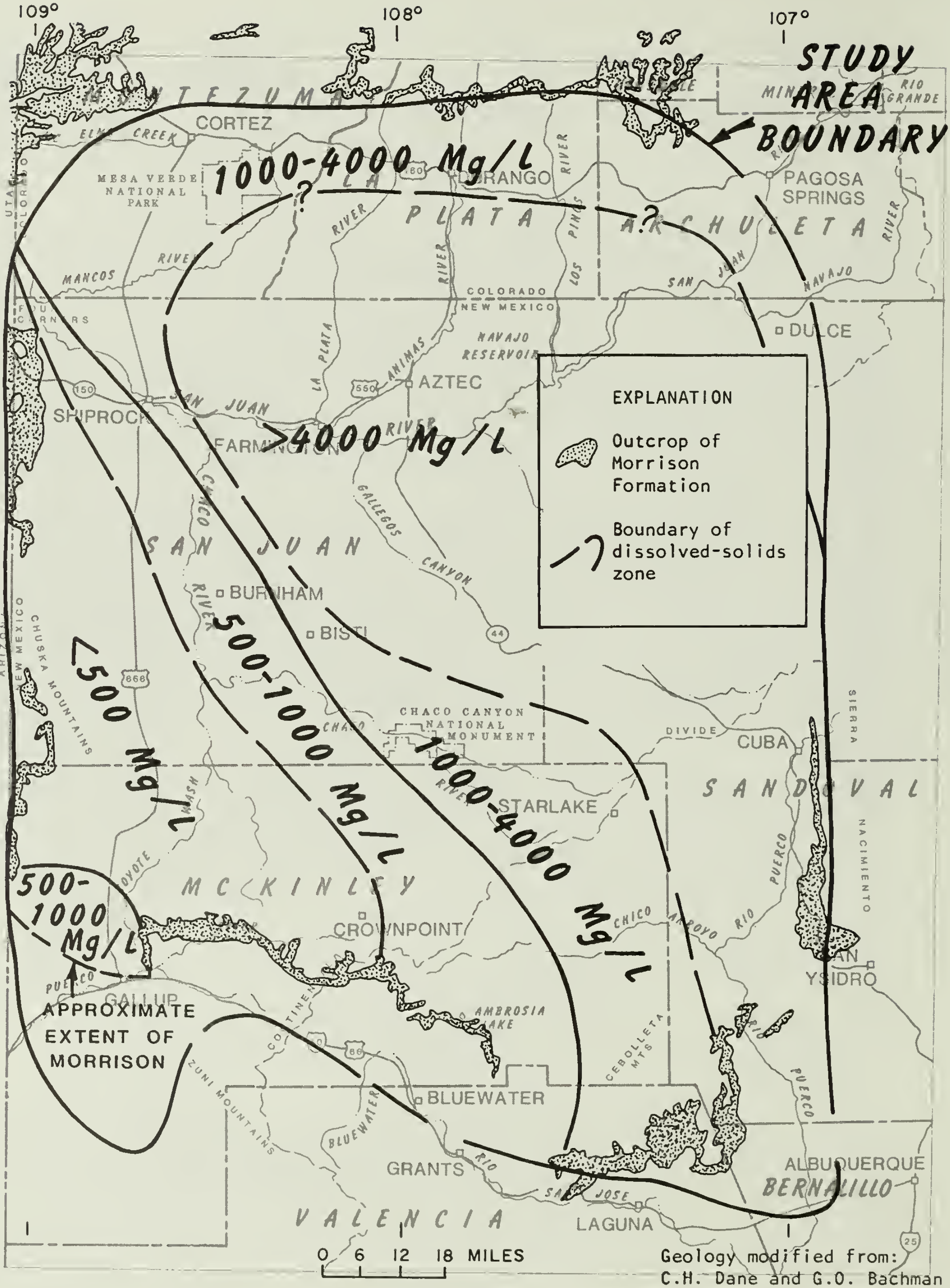


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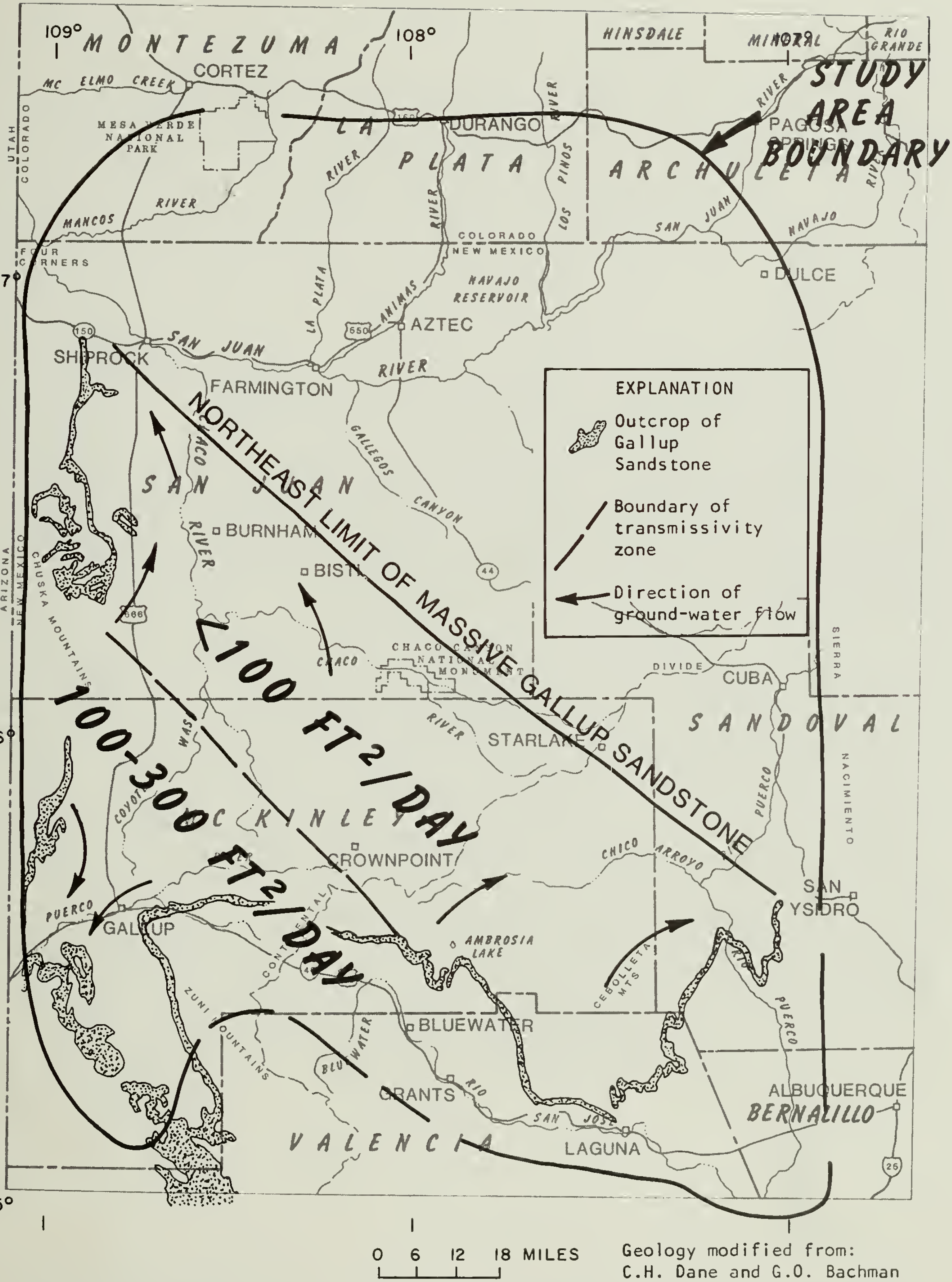
Figure 5.--Dissolved-solids concentration in the Morrison Formation.



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C.H. Dane and G.O. Bachman
(1965)

Figure 6.--Transmissivity and direction of ground-water flow in the Gallup Sandstone of the Mesaverde Group.

Dissolved-solids concentrations of less than 1,000 mg/L occur near Gallup and increase in the direction of ground-water flow (fig. 7). The limited available data indicate that water in the Gallup Sandstone may contain less than 1,000 mg/L of dissolved solids near the Cebolleta Mountains near Grants. Dissolved-solids concentrations in discontinuous sandstones north of the outcrop of the massive Gallup Sandstone exceed 30,000 mg/L (Berry, 1959, p. 107-108).

Younger sandstones of the Mesaverde Group

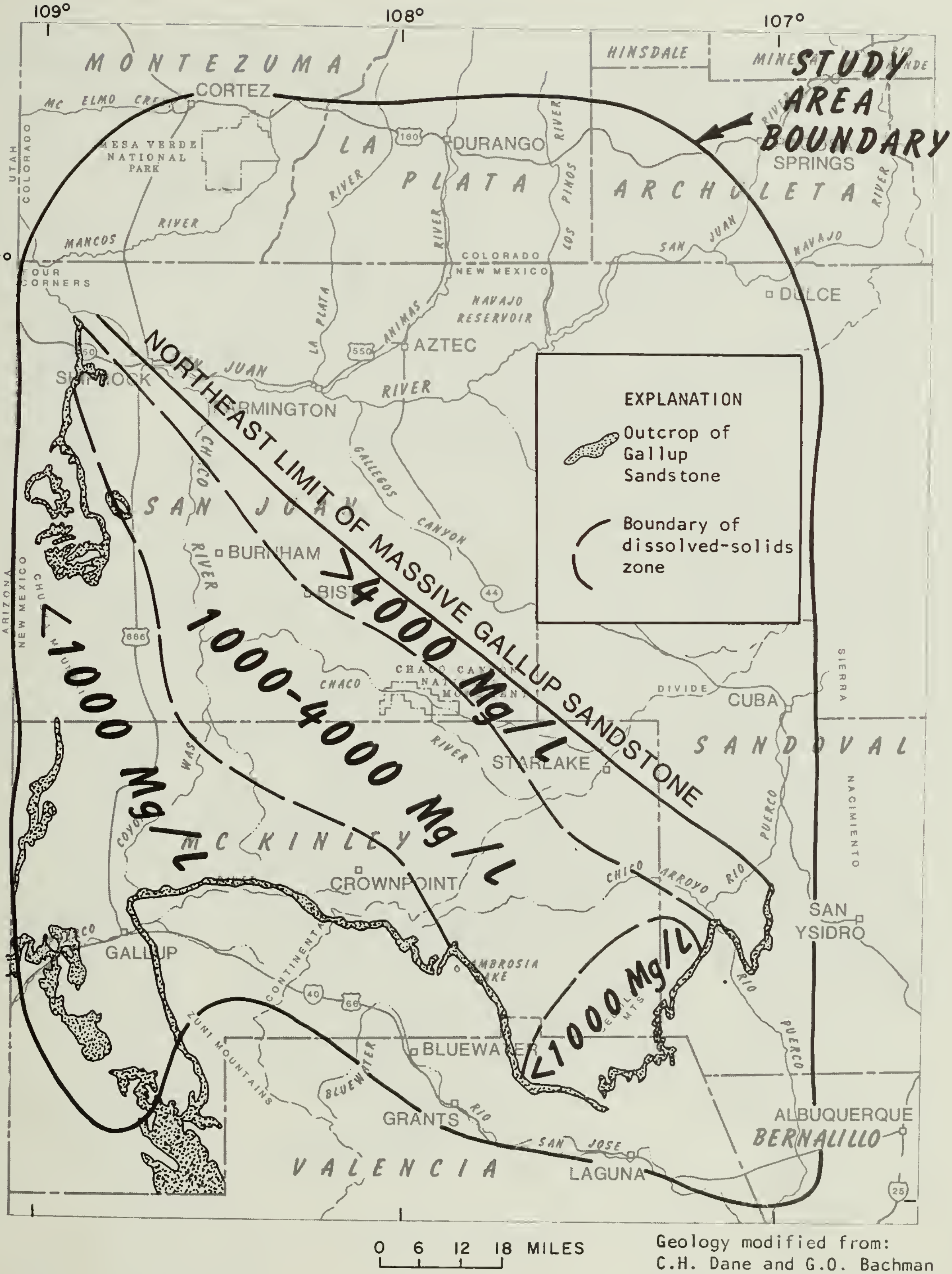
Sandstones of the Mesaverde Group, excluding the Gallup Sandstone, have been combined under one heading in this report because all have similar characteristics. These sandstones include in ascending order the Dalton Sandstone Member of the Crevasse Canyon Formation, Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone. These sandstones are thickest at the south end of the basin (fig. 3).

Recharge to these sandstones is by direct percolation in outcrop areas and by upward leakage from underlying units. As with the other sandstone aquifers in the area, the general direction of flow at the south side of the basin is northwestward and northeastward from the major recharge areas (fig. 8). Discharge is mostly to the land surface or to alluvium-filled channels. Transmissivities of individual sand units such as the Dalton Sandstone Member, Point Lookout Sandstone, and Cliff House Sandstone may exceed 100 ft^2/d in areas of greatest thickness. Generally, transmissivities are less than 50 ft^2/d, particularly in the discontinuous sandstones of the Menefee Formation. Figure 8 shows the approximate transmissivity distribution for the combined sandstones of the Mesaverde Group.

Dissolved-solids concentrations generally exceed 1,000 mg/L except in or near outcrop areas where localized recharge causes lower concentrations (fig. 9). In deeper parts of the basin, particularly where these sandstones contain oil and gas, the concentrations may exceed 30,000 mg/L.

Tertiary rocks

Tertiary rocks include the Ojo Alamo Sandstone, Nacimiento Formation, and San Jose Formation in the northeast part of the basin and the Chuska Sandstone capping the Chuska Mountains on the west side of the basin.



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(1965)

Figure 7.--Dissolved-solids concentration in the Gallup Sandstone of the Mesaverde Group.

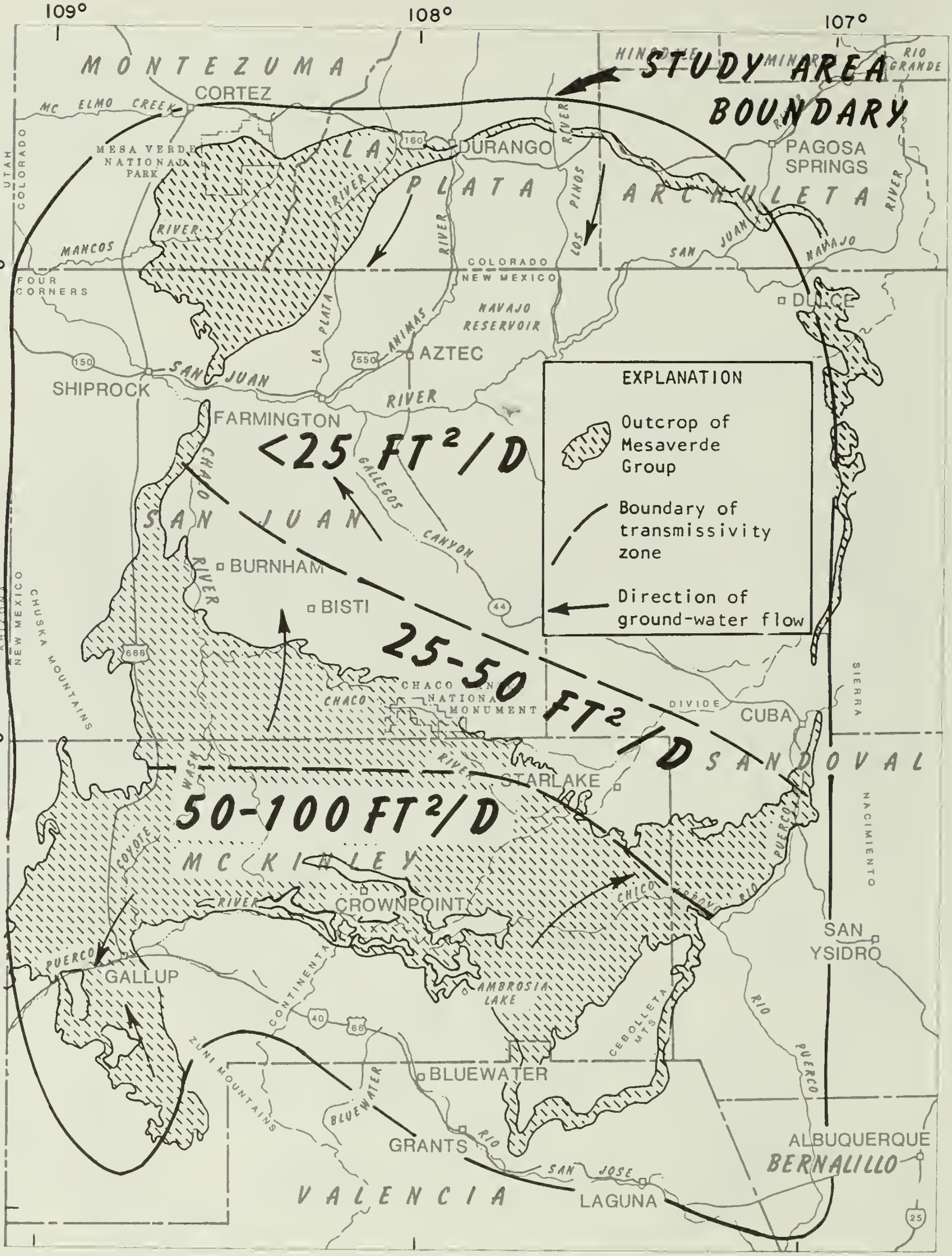

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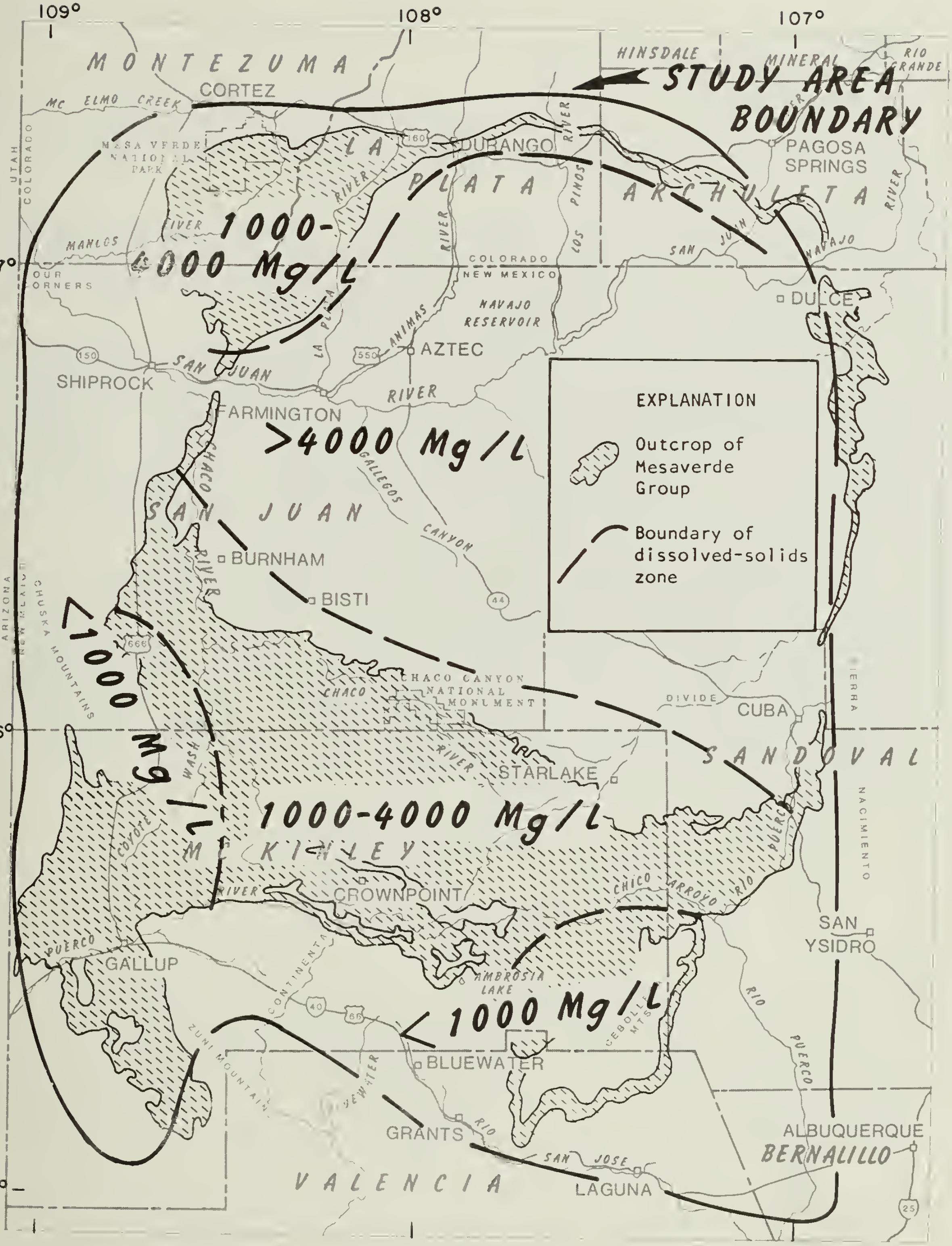
Figure 8.--Transmissivity and direction of ground-water flow in the Mesaverde Group (excluding the Gallup Sandstone).



Geology modified from: C.H. Dane and G.O. Bachman (1965) and O. Tweto (1976)

Figure 9.--Dissolved-solids concentration in the Mesaverde Group (excluding the Gallup Sandstone).

Recharge to the Tertiary sandstones near the center of the basin occurs mostly in outcrop areas. The general direction of flow is toward the San Juan River and lower reaches of major tributaries (fig. 10).

Water recharged to the Chuska Sandstone moves toward springs on the east and west sides of the Chuska Mountains (Harshbarger and Repenning, 1954, p. 6). Water in the Chuska Sandstone also recharges the underlying Jurassic and Cretaceous sandstones.

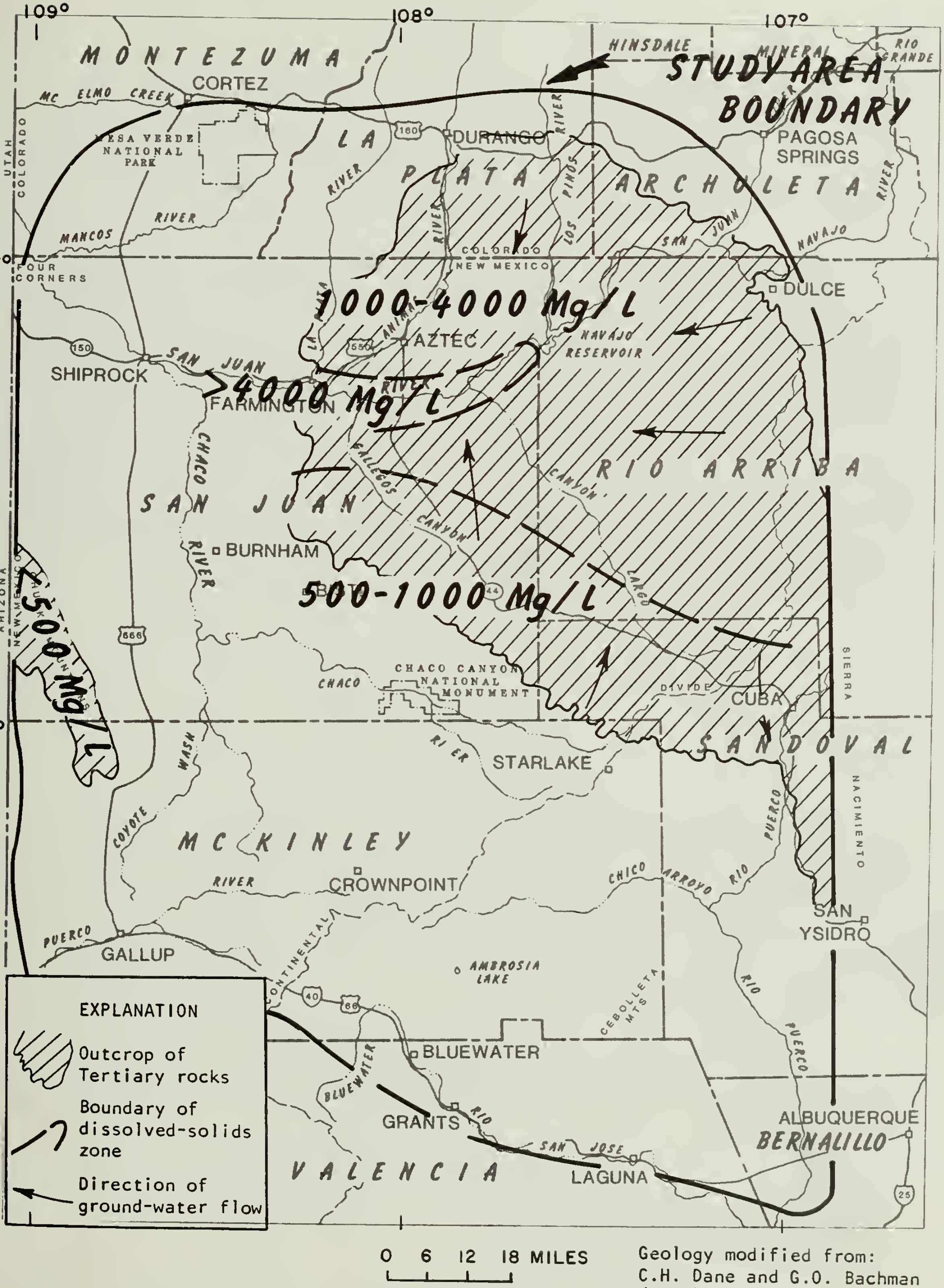
The transmissivity of some of the thicker sandstones such as the Ojo Alamo Sandstone may exceed 150 ft^2/d in some places (Brimhall, 1973, p. 20) but generally does not exceed 100 ft^2/d. Baltz and West (1967, p. 65) indicated that yields of 1,000 gal/min or more may be expected in wells penetrating the full thickness of Tertiary sandstones near the thickest part of the section. The available data is too limited for construction of a transmissivity map.

In general, dissolved-solids concentrations in Tertiary sandstones in the northeast part of the study area exceed 1,000 mg/L and increase in the direction of ground-water flow (fig. 10). Near the San Juan River, concentrations exceeding 4,000 mg/L may be partly attributed to saline water leaking upward from underlying Cretaceous rocks. Generally, concentrations are higher in the finer-grained sediments than in the coarser-grained sediments. Dissolved-solids concentrations in the Chuska Sandstone are less than 500 mg/L (Harshbarger and Repenning, 1954, p. 15).

Valley fill

Saturated valley fill occurs in most of the perennial and ephemeral stream channels. Total thicknesses of valley fill in most areas are less than 50 feet. In parts of the Chaco River, Puerco River, and Rio Puerco channels, however, thicknesses exceeding 100 feet have been reported (David Love, oral commun., 1977; Shomaker, 1971, p. 85; and A. E. Saucier, written commun., 1974).

The transmissivity of valley fill is highest in the coarse gravels along the San Juan, Animas, and La Plata Rivers. Although thicknesses are generally less than 50 feet, the transmissivity may exceed 40,000 ft^2/d in places (T. E. Kelly, written commun., 1977). Transmissivities along ephemeral streams probably do not exceed 1,000 ft^2/d (Shomaker, 1971, p. 87-90 and F. P. Lyford, written commun., 1978).



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(1965) and O. Tweto (1976)

Figure 10.--Direction of ground-water flow and dissolved-solids concentration in Tertiary rocks.

Recharge to valley fill along irrigated portions of the San Juan, Animas, and La Plata Valleys results largely from the percolation of irrigation water and from leaking ditches. Smaller quantities are contributed from bedrock sources. Much of this water is evapotranspired, but some is discharged into the river or drainage ditches.

Recharge to valley fill along ephemeral streams results largely from infiltration of storm flows and snowmelt runoff. In addition, bedrock units contribute water to the valley fill, particularly in lower reaches of the stream. Discharge is by evapotranspiration, infiltration to underlying bedrock units in recharge areas, and movement downstream through the alluvium.

Dissolved solids in valley fill normally increase from less than 1,000 mg/L in headwater areas to more than 2,000 mg/L in lower reaches where water seeping from bedrock units adds dissolved solids (fig. 11). Percolation of applied irrigation water with low dissolved solids (less than 500 mg/L) may improve ground-water quality in parts of the San Juan, Animas, and La Plata River Valleys.

Summary

Principal aquifers in the San Juan Basin of New Mexico and Colorado occur in the coarser-grained sandstones of Jurassic, Cretaceous and Tertiary age. These include the Entrada Sandstone, Westwater Canyon Member of the Morrison Formation, Gallup Sandstone of the Mesaverde Group, several sandstones in the Mesaverde Group above the Gallup (Dalton Sandstone Member of the Crevasse Canyon Formation, Point Lookout Sandstone, Cliff House Sandstone), and sandstones of Tertiary age.

Most ground water flows from recharge areas on topographically high outcrops toward the San Juan River or the Rio Grande rift. Much of the water may move through confining layers to other aquifers, to the land surface, or to alluvium-filled channels.

Transmissivities of the more productive aquifers in the San Juan Basin range from 50 to 300 ft^2/d. Dissolved-solids concentrations range from less than 500 mg/L near recharge areas to more than 10,000 mg/L near discharge areas.

Valley fill near perennial streams and major ephemeral streams normally does not exceed a thickness of 50 feet. Transmissivities range from less than 1,000 ft^2/d in ephemeral channels to more than 40,000 ft^2/d in gravel-filled perennial stream channels.

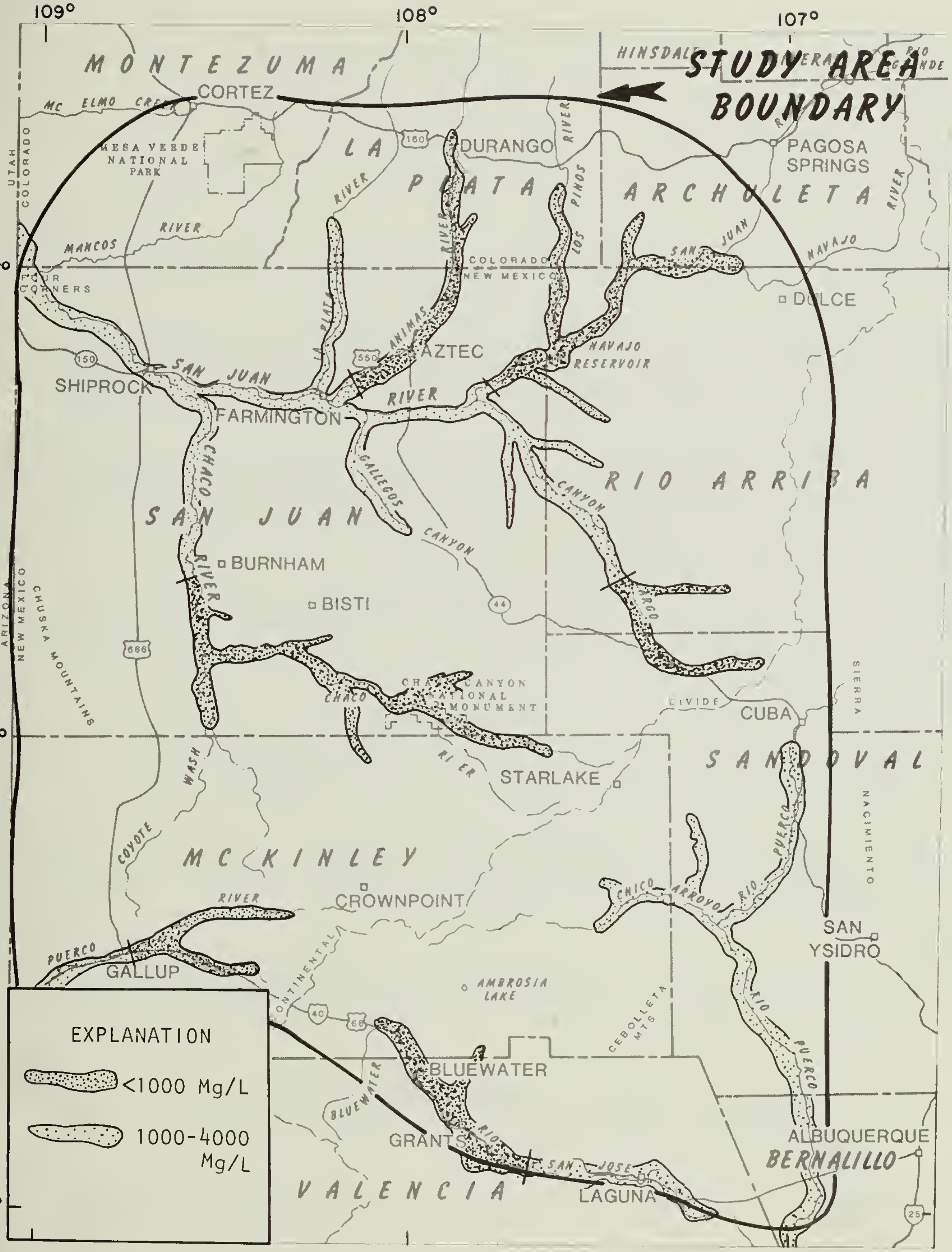

Figure 11.--Dissolved-solids concentration in valley-fill aquifers.

Dissolved-solids concentrations in water from the valley-fill deposits range from less than 1,000 mg/L in headwater areas to more than 4,000 mg/L in some localities where contributions from bedrock sources are significant.

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